

PATENT ABSTRACTS OF JAPAN

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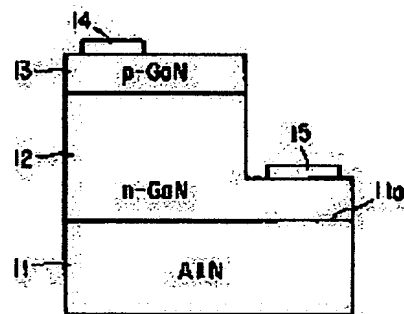
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NITTA KOICHI**(54) COMPOUND SEMICONDUCTOR DEVICE AND COMPOUND SEMICONDUCTOR LIGHT-EMITTING DEVICE**

(57)Abstract:

PROBLEM TO BE SOLVED: To make it possible to form a nitride compound semiconductor film having few crystal defects and to improve the reliability of a light-emitting element.

SOLUTION: In a compound semiconductor light-emitting diode formed using a nitride compound semiconductor crystal, an AlN orientated polycrystalline substrate 11 is used as a crystalline substrate, n-type and p-type GaN layers 12 and 13 are grown and formed on this substrate 11 and ohmic electrodes, which respectively consist of In films 15 and 14, are formed on the layers 12 and 13.

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CLAIMS

[Claim(s)]

[Claim 1] Compound semiconductor equipment characterized by coming to provide the crystalline substrate which consists of stacking tendency polycrystal, and the nitride system compound semiconductor film by which growth formation was carried out on this substrate.

[Claim 2] Said crystalline substrate is compound semiconductor equipment according to claim 1 which carries out the description of being the stacking tendency polycrystal substrate which consists of AlN, GaN, SiC(s), or these solid solutions.

[Claim 3] Said crystalline substrate is compound semiconductor equipment according to claim 1 or 2 which carries out the description of being the stacking tendency polycrystal substrate which has a stacking tendency in the direction of a c-axis.

[Claim 4] Compound semiconductor luminescence equipment characterized by coming to provide the crystalline substrate which consists of stacking tendency polycrystal, and the semiconductor laminating section which has the pn junction or the heterojunction which comes to carry out growth formation of the nitride system compound semiconductor film of two or more layers on this substrate, and serves as a luminous layer at a part.

[Claim 5] Said crystalline substrate is compound semiconductor luminescence equipment according to claim 4 which carries out the description of being the stacking tendency polycrystal substrate which consists of AlN, GaN, SiC(s), or these solid solutions.

[Claim 6] Said crystalline substrate is compound semiconductor luminescence equipment according to claim 4 or 5 which carries out the description of being the stacking tendency polycrystal substrate which has a stacking tendency in the direction of a c-axis.

[Claim 7] Said luminous layer is compound semiconductor luminescence equipment according to claim 4 which carries out the description of having a field from 365nm to 530nm as luminescence wavelength.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the compound semiconductor equipment and compound semiconductor luminescence equipment which consist of a nitride system compound semiconductor formed on the crystalline substrate.

[0002]

[Description of the Prior Art] The nitride system compound semiconductor expressed with AlGaInN is known as current and a blue or purple semiconductor material for light emitting diodes. Conventionally, this ingredient system has mainly grown on silicon on sapphire by metal-organic chemical vapor deposition (MOCVD law). The crystal defect has generated [grid mismatching with a substrate] the nitride system compound semiconductor which grew by this approach by the consistency of 10^8 cm^{-2} to 10^{10} cm^{-2} from a certain thing about 16%.

[0003] About reduction of such a crystal defect consistency, the technique using various buffer layers is tried as indicated by JP,4-15200,B, JP,2-81482,A, JP,4-297023,A, etc. However, since sapphire is used as a substrate in the case of which, the crystal defect generated in the interface of a substrate and a buffer layer cannot be reduced, but a defect spreads to the nitride system compound semiconductor film which grew on the substrate. Therefore, there was a problem in putting in practical use that there are many points inadequate for the dependability of components, such as luminescence strength reduction in a light emitting device and a poor proof pressure in a high proof-pressure component, or it is easy to produce degradation of a component.

[0004] Moreover, conventionally, about the AlN polycrystalline substance, since the thermal conductivity is excellent, it is used as a support substrate which served as heat dissipation. However, such a substrate was a thing without the so-called stacking tendency which does not have the peak of high intensity in a specific include-angle field, when it is used only paying attention to thermal conductivity and an X diffraction was measured. Therefore, when such the polycrystalline substance was used as a substrate for growth of a nitride system compound semiconductor, the nitride system compound semiconductor grown up on the substrate did not become a single crystal, but there was a trouble that a component could not be formed.

[0005]

[Problem(s) to be Solved by the Invention] Thus, in the semiconductor device or semi-conductor luminescence equipment using a nitride system compound semiconductor, there were many crystal defects resulting from the grid mismatching between a substrate and a semi-conductor layer in the nitride system compound semiconductor layer formed on the substrate, and the trouble was in the dependability of components, such as a fall of luminescence reinforcement, and a pressure-proof defect, conventionally.

[0006] This invention was made in consideration of the above-mentioned situation, the place made into the purpose can form the good nitride system compound semiconductor film with few crystal defects, and it is in offering the compound semiconductor equipment and compound semiconductor luminescence equipment which can aim at the improvement in dependability of a component.

[0007]

[Means for Solving the Problem]

(Outline) The following configurations are used for this invention in order to solve the above-mentioned technical problem. That is, in the compound semiconductor equipment with which this invention was equipped with a crystalline substrate and the compound semiconductor film by which growth formation was carried out on this substrate, it is characterized by for a crystalline substrate consisting of a stacking tendency polycrystal substrate, and the compound semiconductor film consisting of nitride system compound semiconductor film.

[0008] Moreover, this invention is characterized by coming to provide the crystalline substrate which consists of stacking tendency polycrystal, and the semi-conductor laminating section which has the pn junction or the heterojunction which comes to carry out growth formation of the nitride system compound semiconductor film of two or more layers on this substrate, and serves as a luminous layer at a part in the compound semiconductor luminescence equipment which used the nitride system compound semiconductor crystal.

[0009] Here, the following are raised as a desirable embodiment of this invention.

(1) A crystalline substrate should be a stacking tendency polycrystal substrate which consists of AlN, GaN, SiC(s), or these solid solutions.

(2) A crystalline substrate should be a stacking tendency polycrystal substrate which has a stacking tendency in the direction of a c-axis.

(3) A luminous layer should have a field from 365nm to 530nm as luminescence wavelength.

(4) as a crystal growth method -- MOCVD -- use law.

(Operation) According to this invention, since stacking tendency polycrystal substrates, such as AlN, GaN, and SiC, are used as a crystalline substrate, the grid mismatching between a substrate and the nitride system compound semiconductor film formed on it becomes small. For this reason, the defect density of the nitride system compound semiconductor film decreases, and, thereby, the dependability of a component improves. Specifically, improvement in the luminescence reinforcement in a light emitting device, the improvement in a proof pressure in a high proof-pressure component, etc. can be aimed at. Moreover, since it has a stacking tendency in the direction of specification [this substrate], a single crystal is formed also in growth of the nitride system compound semiconductor film.

[0010]

[Embodiment of the Invention] Hereafter, the operation gestalt of this invention is explained, referring to a drawing.

(Operation gestalt 1) Drawing 1 is the sectional view showing the component structure of the light emitting diode concerning the 1st operation gestalt of this invention.

[0011] The AlN polycrystal substrate which carried out orientation to the c-axis as a crystalline substrate is used, and the laminating of the n mold GaN layer 12 with a thickness of 4 micrometers and the p mold GaN layer 13 with a thickness of 1 micrometer is carried out on 1 principal-plane 11a of this AlN polycrystal substrate 11. The p mold GaN layer 13 works as a luminous layer. Etching removal of a part of p mold GaN layer 13 is carried out until the n mold GaN layer 12 is exposed. And as an ohmic electrode, the In film 14 is formed on the p mold GaN layer 13, and the In film 15 is formed in the exposed part of the n mold GaN layer 12.

[0012] Next, the manufacture approach of the light emitting diode in this operation gestalt is explained. as a crystal growth method -- MOCVD -- law was used. By this MOCVD method, hydrogen (H₂) was used as carrier gas, and trimethylgallium (CH₃)₃ Ga:TMG, ammonia (NH₃), a silane (SiH₄), and bis(cyclopentadienyl) magnesium (C five H₅)₂ Mg:Cp₂ Mg were used as material gas.

[0013] First, it equips with the AlN polycrystal substrate 11 which washed the front face by organic washing and acid cleaning on the susceptor which was laid in the reaction chamber of an MOCVD system and which can be heated. and ordinary pressure -- H₂ It 10L/Shunted and gas phase etching of the 1 principal-plane 11a of the AlN polycrystal substrate 11 was carried out for about 10 minutes at the temperature of 1100 degrees C inside. In addition, about the creation approach of the stacking tendency polycrystal substrate of AlN, it mentions later.

[0014] Subsequently, the AlN polycrystal substrate 11 is lowered and kept warm at 1050 degrees C, and it is H₂. A part for 10L/, and NH₃ It is 25 cca part for /and SiH₄ about a part for 5L/, and TMG. The GaN layer 12 was formed by [ten cc] passing by /, respectively for about 1 hour.

[0015] Subsequently, it is H₂, keeping the AlN polycrystal substrate 11 warm at 1050 degrees C. A part for 10L/, and NH₃ It is 25 cca part for /and SiH₄ about a part for 5L/, and TMG. The p mold GaN layer 13 was formed for about 15 minutes by pouring a part for /, and ten ccCp2 Mg by 100 cc/, respectively.

[0016] after lowering the AlN polycrystal substrate 11 with which the GaN layers 12 and 13 grew to a room temperature -- from an MOCVD system -- taking out -- SiO₂ etc. -- it considered as the mask, and selective etching of the p mold GaN layer 13 was carried out until the n mold GaN layer 12 was exposed with a hot acid or alkali.

[0017] Subsequently, about 1 micrometer was formed with the vacuum deposition method of common knowledge of In, and it considered as the good ohmic electrode by 300-degree C heat-treatment among nitrogen-gas-atmosphere mind. In addition, the n mold GaN layer 12 was [$3 \times 10^{18} \text{cm}^{-3}$ and the p mold GaN layer 13 of the carrier concentration of each class] $6 \times 10^{16} \text{cm}^{-3}$.

[0018] Thus, the formed light emitting diode is carved into the magnitude of 350-micrometer angle, it mounts on a stem, and a lamp is completed by carrying out mold. Thus, in the formed light emitting diode, there were very few crystal defects in the n mold GaN layer 12 or the p mold GaN layer 13. And as compared with the light emitting diode of the same structure at the time of using conventional silicon on sapphire, energization degradation could not take place easily and the life has been improved a figure single [about].

[0019] In addition, what is necessary is just to create the stacking tendency polycrystal substrate of AlN as follows. Since the liquid phase is not looked at by these ingredient systems in ordinary pressure, stacking tendency polycrystal substrates, such as AlN and SiC, can be created by the sublimating method. SiC -- well-known Rayleigh -- it can create by using law. SiC evaporates this by heating the powder of SiC at an about 2400-degree C elevated temperature (sublimation), and a crystal deposits into the low-temperature part by making the about 2200-degree C low-temperature section to this. Since these ingredient systems tend to have the regularity of an array in the direction of a certain kind at this time, it is possible to create the stacking tendency polycrystalline substance. Such an approach is applicable also to AlN or GaN. In this case, since it is very easy to dissociate nitrogen, creating in nitrogen-gas-atmosphere mind is desirable.

(Operation gestalt 2) Drawing 2 is the sectional view showing the component structure of the light emitting diode concerning the 2nd operation gestalt of this invention.

[0020] The laminating of the GaN buffer layer 22 with a thickness of 20nm, the n mold GaN layer 23 with a thickness of 4 micrometers, and the p mold GaN layer 24 with a thickness of 1 micrometer is carried out to the c-axis from the substrate side on this substrate 21 at order using the AlN polycrystal substrate 21 with a stacking tendency as a crystalline substrate. The GaN buffer layer 22 eases 2.2% of grid mismatching between an AlN stacking tendency polycrystal substrate and a GaN layer, and it forms it in order to control generating of a lattice defect. Moreover, etching removal of a part of p mold GaN layer 24 is carried out until the n mold GaN layer 23 is exposed, and the In layers 25 and 26 as an ohmic electrode are formed in each class 23 and 24.

[0021] As a result of forming a component with such structure, as compared with the 1st operation gestalt in which the direct nitride system compound semiconductor layer was formed on the AlN stacking tendency polycrystal substrate, the crystallinity of a nitride system compound semiconductor layer was improving further, and the improvement was found by the life of a component. Thus, in the formed light emitting diode 20, the life is improvable single or more figures as compared with the case where the same structure is produced using conventional silicon on sapphire.

(Operation gestalt 3) Drawing 3 is the sectional view showing the component structure of the light emitting diode concerning the 3rd operation gestalt of this invention.

[0022] The laminating of the GaN buffer layer 32 with a thickness of 20nm, the p mold GaN layer 33 with a thickness of 4 micrometers, and the n mold GaN layer 34 with a thickness of 1 micrometer is carried out to the c-axis from the substrate side on this substrate 31 at order using the AlN polycrystal substrate 31 with a stacking tendency as a crystalline substrate. Moreover, a part of n mold GaN layer 34 is removed until the p mold GaN layer 33 is exposed, and the In layers 35 and 36 as an ohmic electrode are formed in each class 33 and 34.

[0023] With such structure, since the n mold GaN layer which is comparatively easy to become low resistance according to the difference in mobility is formed in the front face even if it has the same carrier concentration, it is easy to produce the breadth of a current, therefore a large luminescence field can be taken. Therefore, as compared with the 3rd operation gestalt, a 3 to 5 times as many increment as this came to be looked at by luminescence reinforcement.

(Operation gestalt 4) Drawing 4 is the sectional view showing the component structure of the light emitting diode concerning the 4th operation gestalt of this invention.

[0024] The AlN polycrystal substrate 41 which carried out orientation to the c-axis as a crystalline substrate is used. On this substrate 41 Sequentially from a substrate side, the GaN buffer layer 42 with a thickness of 20nm and Si the MOCVD as the 1st operation gestalt with same n mold AlGaIn (presentation ratio of aluminum = 15%) layer 43 with a thickness of 3 micrometers added, n mold InGaIn (presentation ratio of In = 6%) luminous layer 44 with a thickness of 50nm which added Si and Zn to coincidence, and p mold GaN layer 45 with a thickness of 300nm which added Mg -- law It is used and formed.

[0025] It sets by the MOCVD method and is H₂ as carrier gas. And TMG, trimethylaluminum (CH₃) (3 aluminum:TMA), trimethylindium (CH₃) (3 In:TMI), NH₃, SiH₄, Cp₂ Mg, and diethylzinc (C two H₅) (2 Zn:DEZ) were used as nitrogen (N₂) and material gas.

[0026] In the light emitting diode of this operation gestalt, since double hetero structure is formed, as compared with simple gay junction as shown in the operation gestalten from the 1st to the 3rd, the locked-in effect of the carrier in a luminous layer arises strongly, therefore luminescence reinforcement increases remarkably.

[0027] Moreover, in this operation gestalt, although the presentation ratio between In and Ga set up the InGaIn luminous layer 44 with 6%, it can change luminescence wavelength by this presentation ratio. however, the presentation ratio of In -- large -- becoming -- a long wave -- if it is going to assign luminescence wavelength to merit, since a fall will be looked at by the crystallinity of a luminous layer 44, the presentation ratio of In by which luminescence wavelength goes into the range from 365nm to 530nm is desirable. It is desirable for luminescence wavelength to have the presentation ratio of In in the range which is in 480nm from 365nm furthermore.

(Operation gestalt 5) Drawing 5 is the sectional view showing the component structure of the laser diode concerning the 5th operation gestalt of this invention.

[0028] Using the AlN polycrystal substrate 51 which carried out orientation to m shaft (<1-100> shaft) as a crystalline substrate, on it, 20nm in thickness and the n mold GaN layer 53 are formed for the GaN buffer layer 52, and 100nm and 300nm of p mold GaN layers 55 are formed for 4 micrometers and the undoping InGaIn layer 54 in this operation gestalt. And the In-Zn electrode 57 is formed in a stripe with a width of face of 10 micrometers which carried out pattern NINGU of the SiO₂ film 56, and formed it on the p mold GaN layer 55. Furthermore, the In electrode 58 is formed in the n mold GaN layer 53.

[0029] In the semiconductor laser of such structure, although luminescence wavelength changes with the presentations of In in the InGaIn layer 54, it can start laser oscillation from the wavelength of 365nm among 480nm.

(Operation gestalt 6) Drawing 6 is the component structure section Fig. showing the high-speed component HEMT concerning the 6th operation gestalt of this invention (high electron mobility transistor).

[0030] With this operation gestalt, the AlN polycrystal substrate 61 which carried out orientation is used for the c-axis as a crystalline substrate, and it has structure which carried out the laminating of the n mold GaN layer 62 of undoping, and the n mold aluminum 0.15 Ga 0.85 N layer

63 of Si dope in this order on it. The source electrode 64 and the drain electrode 66 consisted of a laminated structure of Ti/Au, and have taken contact in the n mold GaN layer 62 by heat treatment. The gate electrode 65 consists of TiW. The thickness of the n mold GaN layer 62 is 0.6 micrometers, and carrier concentration is $1 \times 10^{17} \text{cm}^{-3}$. The thickness of the n mold AlGaIn layer 63 is 25nm, and carrier concentration is $4 \times 10^{18} \text{cm}^{-3}$.

[0031] Cut off frequency f_T which is the component property in such a component 20GHz and the maximum oscillation frequency f_{max} It has the property which is 50GHz. Moreover, the improvement of about 3 times was able to be found compared with the case where the life of a device is also formed on the silicon on sapphire till then.

(Operation gestalt 7) Drawing 7 is the component structure section Fig. showing the laser diode concerning the 7th operation gestalt of this invention.

[0032] the GaN polycrystal 71 which carried out orientation to the c-axis in this operation gestalt -- as a substrate -- using -- MOCVD of common knowledge on this -- in law, the Si dope n mold GaN layer 72 with a thickness of 100nm was grown up. It grew up in the form which furthermore put the undoping GaN layer 74 with a thickness of 0.1 micrometers on it in the Si dope n mold AlGaIn layer 73 with a thickness of 1 micrometer and the p mold AlGaIn layer 75 (aluminum presentation ratio is 0.25 for all). Furthermore on it, the p mold GaN layer 76 was formed by the thickness of 0.3 micrometers as a cap layer aiming at controlling scaling of an AlGaIn layer.

[0033] $1 \times 10^{18} \text{cm}^{-3}$ and the p mold GaN layer 76 set [the n mold GaN layer 72 / $1 \times 10^{19} \text{cm}^{-3}$ and the n mold AlGaIn layer 73 / $3 \times 10^{18} \text{cm}^{-3}$ and the p mold AlGaIn layer 75] carrier concentration to $1 \times 10^{18} \text{cm}^{-3}$, respectively. as the means for which the n mold GaN layer 72 is exposed -- Cl_2 reactive ion etching (RIE) by gas -- law was used.

[0034] As an electrode, the laminated structure 77 of Ti/Au was used as the ohmic electrode to n mold by performing 700-degree C heat treatment using the laminated structure 78 of nickel/Au to p type layer. In addition, it is SiO_2 on the p mold GaN layer 76 because of a current constriction. The film 79 is formed and it was made for a laminated structure 78 to contact a part of p mold GaN layer 76.

[0035] In the laser diode of such a configuration, laser oscillation arose in electrical-potential-difference abbreviation 5V and threshold current density $8 \times 10^3 \text{ A/cm}$.

(Operation gestalt 8) Drawing 8 is the component structure section Fig. showing the light emitting diode concerning the 8th operation gestalt of this invention.

[0036] In this operation gestalt, a disilane (Si_2H_6) and acetylene (C_2H_2) are used in a well-known CVD method on this, using the SiC polycrystal substrate 81 which carried out orientation to the c-axis as a crystalline substrate, and it is TMG and NH_3 to about 500nm SiC buffer layer 82 and a pan. It used and the GaN buffer layer 83 with a thickness of about 100nm was formed. The laminating of the n mold AlGaIn layer 84 (micrometers [in thickness / 3], carrier concentration $2 \times 10^{18} \text{cm}^{-3}$, aluminum presentation ratio 0.3), the undoping GaN layer 85 (0.2 micrometers in thickness), the p mold AlGaIn layer 86 (micrometer [in thickness / 1], carrier concentration $2 \times 10^{17} \text{cm}^{-3}$, aluminum presentation ratio 0.3), and the p mold GaN layer 87 (nm [in thickness / 300], carrier concentration $2 \times 10^{18} \text{cm}^{-3}$) was carried out in this order succeeding besides.

[0037] Moreover, it is each class to n type layer 84 as a means which carries out electric contact to the n mold AlGaIn layer 84 BCl_3 Dry etching was carried out by gas. To the n mold AlGaIn layer 84, the In-Zn layer 89 was used for the electrode for the In layer 88 to the p mold GaN layer 87.

[0038] In the laser diode of such a configuration, the oscillation with a wavelength [of 1mW of optical outputs] of 380nm was obtained by electrical-potential-difference abbreviation 5V.

(Operation gestalt 9) Drawing 9 is the structure section Fig. showing the laser diode concerning the 9th operation gestalt of this invention. In this operation gestalt, the SiC polycrystal 91 which carried out orientation to the c-axis is used as a substrate. This substrate 91 is giving the conductivity of n mold strongly by adding nitrogen in the process of substrate formation. the CVD method of common knowledge on this substrate 91 -- setting -- MOCVD of the SiC buffer

layer 92 with a thickness of about 100nm and common knowledge -- law -- setting -- continuing -- the n mold GaN layer 93 with a thickness of 3 micrometers and the n mold AlGaIn cladding layer 94 (aluminum presentation ratio = 30%) with a thickness of 500nm -- The laminating of the InGaIn barrier layer 95 (In presentation ratio = 10%) and the p mold GaN contact layer 97 with a thickness of 500nm was carried out to undoping with a thickness of 100nm in this order. Moreover, as an electrode, it is SiO₂ to the SiC polycrystal substrate 91 and the p mold GaN layer 97 about the laminated structure 99 of nickel with a thickness of 300nm and Au with a thickness of 1 micrometer, respectively. It formed by controlling stripe width of face by the film 98.

[0039] In the laser diode of such a configuration, since it is not necessary to perform etching processing to the epitaxial growth phases 93-97, the component of low resistance can be formed. That is, laser oscillation was able to be produced in the low threshold.

(Operation gestalt 10) Drawing 10 is the structure section Fig. showing the light emitting diode concerning the 10th operation gestalt of this invention. the solid solution 101 of SiC and AlN which carried out orientation to the c-axis in this operation gestalt -- as a substrate -- using -- MOCVD of common knowledge on this -- the laminating of the GaN buffer layer 102 with a thickness of 50nm, the n mold GaN layer 103 with a thickness of 3 micrometers, the InGaIn (In presentation ratio = 6%) layer 104 with a thickness of 100nm, and the p mold GaN layer 105 with a thickness of 500nm is continuously carried out in this order using law. Moreover, the laminated structure 106 of nickel with a thickness of 300nm and Au with a thickness of 1 micrometer is formed to a substrate 101 and the p mold GaN layer 105, respectively as an electrode.

[0040] In such light emitting diode 100, the electron affinity of a substrate can form the ohmic electrode of low resistance easily from a small thing. Therefore, the power concerning a component can be reduced.

[0041] In addition, this invention is not limited to each operation gestalt mentioned above, it is the range which does not deviate from the summary, and can deform variously and can be carried out. For example, although the polycrystal which carried out orientation to the c-axis and m shaft about the operation gestalt was used as a substrate, the same effectiveness can be acquired even when what carried out orientation to the a-axis (<11-20> shaft), R shaft (<1-102> shaft), etc. is used as a substrate.

[0042] moreover, the grown method of the nitride system compound semiconductor film -- MOCVD -- what is restricted to law -- it is not -- MBE -- it is also possible to use law (molecular beam epitaxy method) and crystal growth methods generally learned, such as hydride vapor growth.

[0043] Moreover, although the operation gestalt explained the light emitting device and the velocity-of-light component HEMT, it is also possible by using the stacking tendency polycrystal of AlN, GaN, and SiC with a near lattice constant for the substrate for nitride system compound semiconductor growth to create the power device of high pressure-proofing etc.

[0044]

[Effect of the Invention] As explained in full detail above, as a substrate for crystal growth of a nitride system compound semiconductor, by using stacking tendency polycrystals, such as AlN, GaN, and SiC, generating of a crystal defect was controlled and, according to this invention, crystalline improvement was able to be aimed at. This becomes possible to attain the improvement in a component property, and reinforcement.

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TECHNICAL FIELD

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PRIOR ART

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[0004] Moreover, conventionally, about the AlN polycrystalline substance, since the thermal conductivity is excellent, it is used as a support substrate which served as heat dissipation. However, such a substrate was a thing without the so-called stacking tendency which does not have the peak of high intensity in a specific include-angle field, when it is used only paying attention to thermal conductivity and an X diffraction was measured. Therefore, when such the polycrystalline substance was used as a substrate for growth of a nitride system compound semiconductor, the nitride system compound semiconductor grown up on the substrate did not become a single crystal, but there was a trouble that a component could not be formed.

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EFFECT OF THE INVENTION

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Thus, in the semiconductor device or semi-conductor luminescence equipment using a nitride system compound semiconductor, there were many crystal defects resulting from the grid mismatching between a substrate and a semi-conductor layer in the nitride system compound semiconductor layer formed on the substrate, and the trouble was in the dependability of components, such as a fall of luminescence reinforcement, and a pressure-proof defect, conventionally.

[0006] This invention was made in consideration of the above-mentioned situation, the place made into the purpose can form the good nitride system compound semiconductor film with few crystal defects, and it is in offering the compound semiconductor equipment and compound semiconductor luminescence equipment which can aim at the improvement in dependability of a component.

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MEANS

[Means for Solving the Problem]

(Outline) The following configurations are used for this invention in order to solve the above-mentioned technical problem. That is, in the compound semiconductor equipment with which this invention was equipped with a crystalline substrate and the compound semiconductor film by which growth formation was carried out on this substrate, it is characterized by for a crystalline substrate consisting of a stacking tendency polycrystal substrate, and the compound semiconductor film consisting of nitride system compound semiconductor film.

[0008] Moreover, this invention is characterized by coming to provide the crystalline substrate which consists of stacking tendency polycrystal, and the semi-conductor laminating section which has the pn junction or the heterojunction which comes to carry out growth formation of the nitride system compound semiconductor film of two or more layers on this substrate, and serves as a luminous layer at a part in the compound semiconductor luminescence equipment which used the nitride system compound semiconductor crystal.

[0009] Here, the following are raised as a desirable embodiment of this invention.

- (1) A crystalline substrate should be a stacking tendency polycrystal substrate which consists of AlN, GaN, SiC(s), or these solid solutions.
- (2) A crystalline substrate should be a stacking tendency polycrystal substrate which has a stacking tendency in the direction of a c-axis.
- (3) A luminous layer should have a field from 365nm to 530nm as luminescence wavelength.
- (4) as a crystal growth method -- MOCVD -- use law.

[Translation done.]

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OPERATION

(Operation) According to this invention, since stacking tendency polycrystal substrates, such as AlN, GaN, and SiC, are used as a crystalline substrate, the grid mismatching between a substrate and the nitride system compound semiconductor film formed on it becomes small. For this reason, the defect density of the nitride system compound semiconductor film decreases, and, thereby, the dependability of a component improves. Specifically, improvement in the luminescence reinforcement in a light emitting device, the improvement in a proof pressure in a high proof-pressure component, etc. can be aimed at. Moreover, since it has a stacking tendency in the direction of specification [this substrate], a single crystal is formed also in growth of the nitride system compound semiconductor film.

[0010]

[Embodiment of the Invention] Hereafter, the operation gestalt of this invention is explained, referring to a drawing.

(Operation gestalt 1) Drawing 1 is the sectional view showing the component structure of the light emitting diode concerning the 1st operation gestalt of this invention.

[0011] The AlN polycrystal substrate which carried out orientation to the c-axis as a crystalline substrate is used, and the laminating of the n mold GaN layer 12 with a thickness of 4 micrometers and the p mold GaN layer 13 with a thickness of 1 micrometer is carried out on 1 principal-plane 11a of this AlN polycrystal substrate 11. The p mold GaN layer 13 works as a luminous layer. Etching removal of a part of p mold GaN layer 13 is carried out until the n mold GaN layer 12 is exposed. And as an ohmic electrode, the In film 14 is formed on the p mold GaN layer 13, and the In film 15 is formed in the exposed part of the n mold GaN layer 12.

[0012] Next, the manufacture approach of the light emitting diode in this operation gestalt is explained. as a crystal growth method -- MOCVD -- law was used. By this MOCVD method, hydrogen (H₂) was used as carrier gas, and trimethylgallium (CH₃)₃ Ga:TMG, ammonia (NH₃), a silane (SiH₄), and bis(cyclopentadienyl) magnesium (C five H₅)₂ Mg:Cp₂ Mg were used as material gas.

[0013] First, it equips with the AlN polycrystal substrate 11 which washed the front face by organic washing and acid cleaning on the susceptor which was laid in the reaction chamber of an MOCVD system and which can be heated. and ordinary pressure -- H₂ It 10L/Shunted and gas phase etching of the 1 principal-plane 11a of the AlN polycrystal substrate 11 was carried out for about 10 minutes at the temperature of 1100 degrees C inside. In addition, about the creation approach of the stacking tendency polycrystal substrate of AlN, it mentions later.

[0014] Subsequently, the AlN polycrystal substrate 11 is lowered and kept warm at 1050 degrees C, and it is H₂. A part for 10L/, and NH₃ It is 25 cca part for /and SiH₄ about a part for 5L/, and TMG. The GaN layer 12 was formed by [ten cc] passing by /, respectively for about 1 hour.

[0015] Subsequently, it is H₂, keeping the AlN polycrystal substrate 11 warm at 1050 degrees C. A part for 10L/, and NH₃ It is 25 cca part for /and SiH₄ about a part for 5L/, and TMG. The p mold GaN layer 13 was formed for about 15 minutes by pouring a part for /, and ten ccCp₂ Mg by 100 cc/, respectively.

[0016] after lowering the AlN polycrystal substrate 11 with which the GaN layers 12 and 13 grew to a room temperature -- from an MOCVD system -- taking out -- SiO₂ etc. -- it considered

as the mask, and selective etching of the p mold GaN layer 13 was carried out until the n mold GaN layer 12 was exposed with a hot acid or alkali.

[0017] Subsequently, about 1 micrometer was formed with the vacuum deposition method of common knowledge of In, and it considered as the good ohmic electrode by 300-degree C heat-treatment among nitrogen-gas-atmosphere mind. In addition, the n mold GaN layer 12 was [$3 \times 10^{18} \text{cm}^{-3}$ and the p mold GaN layer 13 of the carrier concentration of each class] $6 \times 10^{16} \text{cm}^{-3}$.

[0018] Thus, the formed light emitting diode is carved into the magnitude of 350-micrometer angle, it mounts on a stem, and a lamp is completed by carrying out mold. Thus, in the formed light emitting diode, there were very few crystal defects in the n mold GaN layer 12 or the p mold GaN layer 13. And as compared with the light emitting diode of the same structure at the time of using conventional silicon on sapphire, energization degradation could not take place easily and the life has been improved a figure single [about].

[0019] In addition, what is necessary is just to create the stacking tendency polycrystal substrate of AlN as follows. Since the liquid phase is not looked at by these ingredient systems in ordinary pressure, stacking tendency polycrystal substrates, such as AlN and SiC, can be created by the sublimating method. SiC -- well-known Rayleigh -- it can create by using law. SiC evaporates this by heating the powder of SiC at an about 2400-degree C elevated temperature (sublimation), and a crystal deposits into the low-temperature part by making the about 2200-degree C low-temperature section to this. Since these ingredient systems tend to have the regularity of an array in the direction of a certain kind at this time, it is possible to create the stacking tendency polycrystalline substance. Such an approach is applicable also to AlN or GaN. In this case, since it is very easy to dissociate nitrogen, creating in nitrogen-gas-atmosphere mind is desirable.

(Operation gestalt 2) Drawing 2 is the sectional view showing the component structure of the light emitting diode concerning the 2nd operation gestalt of this invention.

[0020] The laminating of the GaN buffer layer 22 with a thickness of 20nm, the n mold GaN layer 23 with a thickness of 4 micrometers, and the p mold GaN layer 24 with a thickness of 1 micrometer is carried out to the c-axis from the substrate side on this substrate 21 at order using the AlN polycrystal substrate 21 with a stacking tendency as a crystalline substrate. The GaN buffer layer 22 eases 2.2% of grid mismatching between an AlN stacking tendency polycrystal substrate and a GaN layer, and it forms it in order to control generating of a lattice defect. Moreover, etching removal of a part of p mold GaN layer 24 is carried out until the n mold GaN layer 23 is exposed, and the In layers 25 and 26 as an ohmic electrode are formed in each class 23 and 24.

[0021] As a result of forming a component with such structure, as compared with the 1st operation gestalt in which the direct nitride system compound semiconductor layer was formed on the AlN stacking tendency polycrystal substrate, the crystallinity of a nitride system compound semiconductor layer was improving further, and the improvement was found by the life of a component. Thus, in the formed light emitting diode 20, the life is improvable single or more figures as compared with the case where the same structure is produced using conventional silicon on sapphire.

(Operation gestalt 3) Drawing 3 is the sectional view showing the component structure of the light emitting diode concerning the 3rd operation gestalt of this invention.

[0022] The laminating of the GaN buffer layer 32 with a thickness of 20nm, the p mold GaN layer 33 with a thickness of 4 micrometers, and the n mold GaN layer 34 with a thickness of 1 micrometer is carried out to the c-axis from the substrate side on this substrate 31 at order using the AlN polycrystal substrate 31 with a stacking tendency as a crystalline substrate. Moreover, a part of n mold GaN layer 34 is removed until the p mold GaN layer 33 is exposed, and the In layers 35 and 36 as an ohmic electrode are formed in each class 33 and 34.

[0023] With such structure, since the n mold GaN layer which is comparatively easy to become low resistance according to the difference in mobility is formed in the front face even if it has the same carrier concentration, it is easy to produce the breadth of a current, therefore a large

luminescence field can be taken. Therefore, as compared with the 3rd operation gestalt, a 3 to 5 times as many increment as this came to be looked at by luminescence reinforcement.

(Operation gestalt 4) Drawing 4 is the sectional view showing the component structure of the light emitting diode concerning the 4th operation gestalt of this invention.

[0024] The AlN polycrystal substrate 41 which carried out orientation to the c-axis as a crystalline substrate is used. On this substrate 41 Sequentially from a substrate side, the GaN buffer layer 42 with a thickness of 20nm and Si the MOCVD as the 1st operation gestalt with same n mold AlGaIn (presentation ratio of aluminum = 15%) layer 43 with a thickness of 3 micrometers added, n mold InGaIn (presentation ratio of In = 6%) luminous layer 44 with a thickness of 50nm which added Si and Zn to coincidence, and p mold GaN layer 45 with a thickness of 300nm which added Mg -- law It is used and formed.

[0025] It sets by the MOCVD method and is H₂ as carrier gas. And TMG, trimethylaluminum (CH₃)₃ aluminum:TMA, trimethylindium (CH₃)₃ In:TMI, NH₃, SiH₄, Cp₂ Mg, and diethylzinc (C two H₅)₂ Zn:DEZ were used as nitrogen (N₂) and material gas.

[0026] In the light emitting diode of this operation gestalt, since double hetero structure is formed, as compared with simple gay junction as shown in the operation gestalten from the 1st to the 3rd, the locked-in effect of the carrier in a luminous layer arises strongly, therefore luminescence reinforcement increases remarkably.

[0027] Moreover, in this operation gestalt, although the presentation ratio between In and Ga set up the InGaIn luminous layer 44 with 6%, it can change luminescence wavelength by this presentation ratio. however, the presentation ratio of In -- large -- becoming -- a long wave -- if it is going to assign luminescence wavelength to merit, since a fall will be looked at by the crystallinity of a luminous layer 44, the presentation ratio of In by which luminescence wavelength goes into the range from 365nm to 530nm is desirable. It is desirable for luminescence wavelength to have the presentation ratio of In in the range which is in 480nm from 365nm furthermore.

(Operation gestalt 5) Drawing 5 is the sectional view showing the component structure of the laser diode concerning the 5th operation gestalt of this invention.

[0028] Using the AlN polycrystal substrate 51 which carried out orientation to m shaft (<1-100> shaft) as a crystalline substrate, on it, 20nm in thickness and the n mold GaN layer 53 are formed for the GaN buffer layer 52, and 100nm and 300nm of p mold GaN layers 55 are formed for 4 micrometers and the undoping InGaIn layer 54 in this operation gestalt. And the In-Zn electrode 57 is formed in a stripe with a width of face of 10 micrometers which carried out pattern NINGU of the SiO₂ film 56, and formed it on the p mold GaN layer 55. Furthermore, the In electrode 58 is formed in the n mold GaN layer 53.

[0029] In the semiconductor laser of such structure, although luminescence wavelength changes with the presentations of In in the InGaIn layer 54, it can start laser oscillation from the wavelength of 365nm among 480nm.

(Operation gestalt 6) Drawing 6 is the component structure section Fig. showing the high-speed component HEMT concerning the 6th operation gestalt of this invention (high electron mobility transistor).

[0030] With this operation gestalt, the AlN polycrystal substrate 61 which carried out orientation is used for the c-axis as a crystalline substrate, and it has structure which carried out the laminating of the n mold GaN layer 62 of undoping, and the n mold aluminum 0.15 Ga 0.85 N layer 63 of Si dope in this order on it. The source electrode 64 and the drain electrode 66 consisted of a laminated structure of Ti/Au, and have taken contact in the n mold GaN layer 62 by heat treatment. The gate electrode 65 consists of TiW. The thickness of the n mold GaN layer 62 is 0.6 micrometers, and carrier concentration is $1 \times 10^{17} \text{cm}^{-3}$. The thickness of the n mold AlGaIn layer 63 is 25nm, and carrier concentration is $4 \times 10^{18} \text{cm}^{-3}$.

[0031] Cut off frequency f_T which is the component property in such a component 20GHz and the maximum oscillation frequency f_{max} It has the property which is 50GHz. Moreover, the improvement of about 3 times was able to be found compared with the case where the life of a device is also formed on the silicon on sapphire till then.

(Operation gestalt 7) Drawing 7 is the component structure section Fig. showing the laser diode concerning the 7th operation gestalt of this invention.

[0032] the GaN polycrystal 71 which carried out orientation to the c-axis in this operation gestalt -- as a substrate -- using -- MOCVD of common knowledge on this -- in law, the Si dope n mold GaN layer 72 with a thickness of 100nm was grown up. It grew up in the form which furthermore put the undoping GaN layer 74 with a thickness of 0.1 micrometers on it in the Si dope n mold AlGaIn layer 73 with a thickness of 1 micrometer and the p mold AlGaIn layer 75 (aluminum presentation ratio is 0.25 for all). Furthermore on it, the p mold GaN layer 76 was formed by the thickness of 0.3 micrometers as a cap layer aiming at controlling scaling of an AlGaIn layer.

[0033] $1 \times 10^{18} \text{cm}^{-3}$ and the p mold GaN layer 76 set [the n mold GaN layer 72 / $1 \times 10^{19} \text{cm}^{-3}$ and the n mold AlGaIn layer 73 / $3 \times 10^{18} \text{cm}^{-3}$ and the p mold AlGaIn layer 75] carrier concentration to $1 \times 10^{18} \text{cm}^{-3}$, respectively. as the means for which the n mold GaN layer 72 is exposed -- Cl_2 reactive ion etching (RIE) by gas -- law was used.

[0034] As an electrode, the laminated structure 77 of Ti/Au was used as the ohmic electrode to n mold by performing 700-degree C heat treatment using the laminated structure 78 of nickel/Au to p type layer. In addition, it is SiO_2 on the p mold GaN layer 76 because of a current constriction. The film 79 is formed and it was made for a laminated structure 78 to contact a part of p mold GaN layer 76.

[0035] In the laser diode of such a configuration, laser oscillation arose in electrical-potential-difference abbreviation 5V and threshold current density $8 \times 10^3 \text{ A/cm}$.

(Operation gestalt 8) Drawing 8 is the component structure section Fig. showing the light emitting diode concerning the 8th operation gestalt of this invention.

[0036] In this operation gestalt, a disilane (Si two H_6) and acetylene (C two H_2) are used in a well-known CVD method on this, using the SiC polycrystal substrate 81 which carried out orientation to the c-axis as a crystalline substrate, and it is TMG and NH_3 to about 500nm SiC buffer layer 82 and a pan. It used and the GaN buffer layer 83 with a thickness of about 100nm was formed. The laminating of the n mold AlGaIn layer 84 (micrometers [in thickness / 3], carrier concentration $2 \times 10^{18} \text{cm}^{-3}$, aluminum presentation ratio 0.3), the undoping GaN layer 85 (0.2 micrometers in thickness), the p mold AlGaIn layer 86 (micrometer [in thickness / 1], carrier concentration $2 \times 10^{17} \text{cm}^{-3}$, aluminum presentation ratio 0.3), and the p mold GaN layer 87 (nm [in thickness / 300], carrier concentration $2 \times 10^{18} \text{cm}^{-3}$) was carried out in this order succeeding besides.

[0037] Moreover, it is each class to n type layer 84 as a means which carries out electric contact to the n mold AlGaIn layer 84 BCl₃ Dry etching was carried out by gas. To the n mold AlGaIn layer 84, the In-Zn layer 89 was used for the electrode for the In layer 88 to the p mold GaN layer 87.

[0038] In the laser diode of such a configuration, the oscillation with a wavelength [of 1mW of optical outputs] of 380nm was obtained by electrical-potential-difference abbreviation 5V.

(Operation gestalt 9) Drawing 9 is the structure section Fig. showing the laser diode concerning the 9th operation gestalt of this invention. In this operation gestalt, the SiC polycrystal 91 which carried out orientation to the c-axis is used as a substrate. This substrate 91 is giving the conductivity of n mold strongly by adding nitrogen in the process of substrate formation. the CVD method of common knowledge on this substrate 91 -- setting -- MOCVD of the SiC buffer layer 92 with a thickness of about 100nm and common knowledge -- law -- setting -- continuing -- the n mold GaN layer 93 with a thickness of 3 micrometers and the n mold AlGaIn cladding layer 94 (aluminum presentation ratio = 30%) with a thickness of 500nm -- The laminating of the InGaIn barrier layer 95 (In presentation ratio = 10%) and the p mold GaN contact layer 97 with a thickness of 500nm was carried out to undoping with a thickness of 100nm in this order. Moreover, as an electrode, it is SiO_2 to the SiC polycrystal substrate 91 and the p mold GaN layer 97 about the laminated structure 99 of nickel with a thickness of 300nm and Au with a thickness of 1 micrometer, respectively. It formed by controlling stripe width of face by the film 98.

[0039] In the laser diode of such a configuration, since it is not necessary to perform etching processing to the epitaxial growth phases 93-97, the component of low resistance can be formed. That is, laser oscillation was able to be produced in the low threshold.

(Operation gestalt 10) Drawing 10 is the structure section Fig. showing the light emitting diode concerning the 10th operation gestalt of this invention.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The sectional view showing the component structure of the light emitting diode concerning the 1st operation gestalt.

[Drawing 2] The sectional view showing the component structure of the light emitting diode concerning the 2nd operation gestalt.

[Drawing 3] The sectional view showing the component structure of the light emitting diode concerning the 3rd operation gestalt.

[Drawing 4] The sectional view showing the component structure of the light emitting diode concerning the 4th operation gestalt.

[Drawing 5] The sectional view showing the component structure of the laser diode concerning the 5th operation gestalt.

[Drawing 6] The sectional view showing the component structure of HEMT concerning the 6th operation gestalt.

[Drawing 7] The sectional view showing the component structure of the laser diode concerning the 7th operation gestalt.

[Drawing 8] The sectional view showing the component structure of the laser diode concerning the 8th operation gestalt.

[Drawing 9] The sectional view showing the component structure of the laser diode concerning the 9th operation gestalt.

[Drawing 10] The sectional view showing the component structure of the light emitting diode concerning the 10th operation gestalt.

[Description of Notations]

11 -- AlN polycrystal substrate (crystalline substrate)

12 -- n mold GaN layer

13 -- p mold GaN layer

14 15 -- In film (electrode)

[Translation done.]

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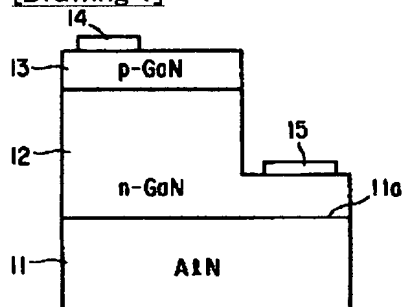
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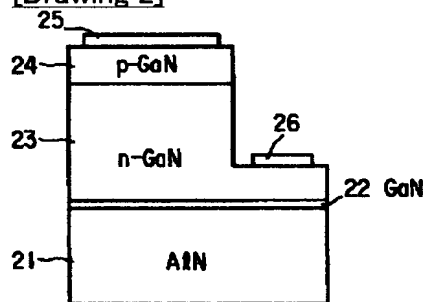
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DRAWINGS

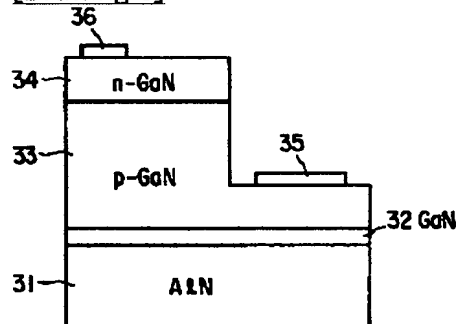
[Drawing 1]



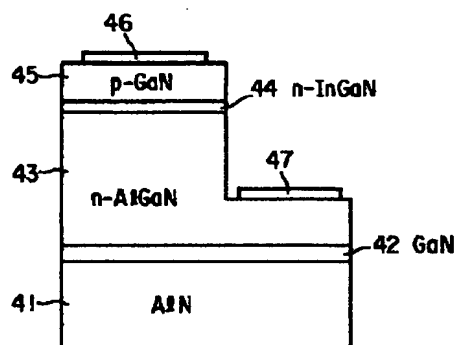
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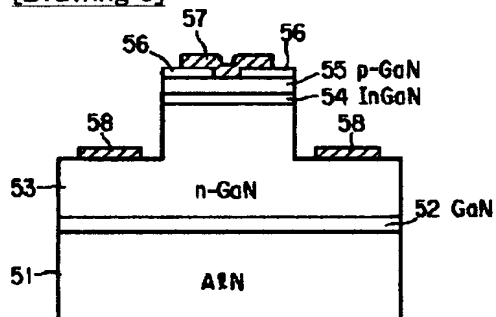
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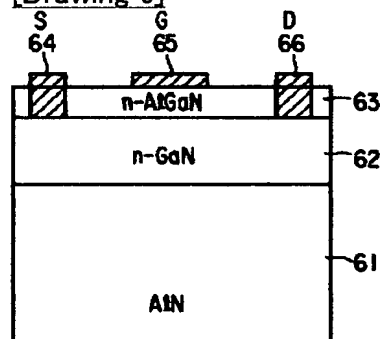
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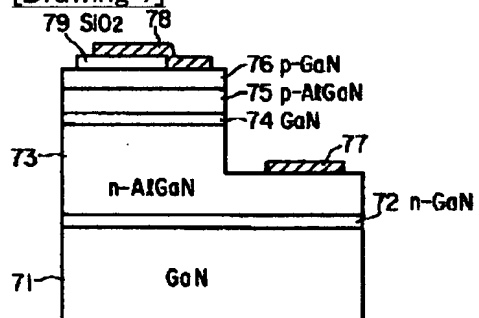
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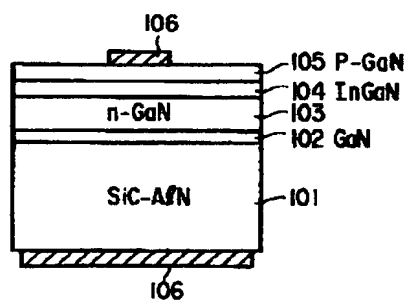
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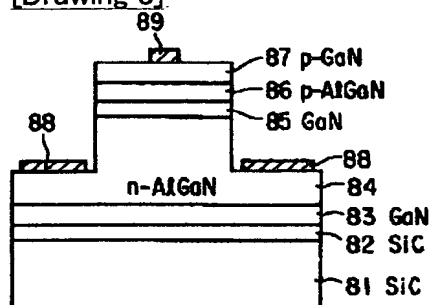
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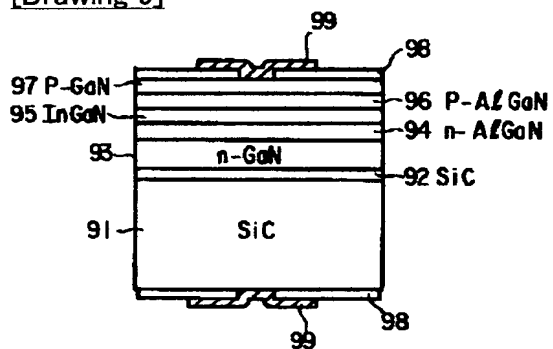
[Drawing 10]



[Drawing 8]



[Drawing 9]



[Translation done.]